Aspen Center for Physics Education and Outreach
June 28 – July 11, 2004
Report

Affecting the State of Physics Education:
Vision for Communicating Physics in the 21st Century
www-ed.fnal.gov/aspen

Executive Summary

Physicists are excited and fascinated by what they observe in nature and the universe. Sharing this excitement with the students and the public is rewarding to them as individuals and is extraordinarily beneficial for democratic societies. This workshop brought together participants from three fields of physics with formal and informal science educators to share successes and build new relationships to bring outstanding domestic students to careers in science and develop a scientifically literate populace.

A strength of this education and outreach workshop was the reinforcement of existing bonds and the establishment of new links among research, formal education, informal education and information technology/media participants. From the talks and discussions came several proposals for significant steps, such as holding a workshop for researchers new to education and outreach, holding sessions at meetings for department chairs and new faculty and establishing a virtual organization that falls within the *Understanding the Universe* framework.

The workshop organizers are grateful for grants received from:

- The NSF Directorate for Mathematical and Physical Sciences (MPS): Physics (PHY) Division and Office of Multidisciplinary Activities (OMA). www.nsf.gov
- The Institute for Complex Adaptive Matter. www.lanl.gov/mst/ICAM/
- The APS Topical Group on Statistical and Nonlinear Physics. www.aps.org/units/gsnp/
- The APS Division of Particles and Fields. www.aps.org/units/dpf/

The workshop also benefited greatly from the hospitality of the Aspen Center for Physics, which provided a collegial atmosphere, additional physicists with whom to interact and significant logistical and in-kind support.

Introduction

Physicists are excited and fascinated by what they observe in nature and the universe. Sharing this excitement with the students and the public is rewarding to them as individuals and is extraordinarily beneficial for democratic societies.

Physicists can play a major role in creating a science-aware society and also in attracting new generations of students to careers in science. More than any time in the past, our citizens need a basic understanding of how science is done, why science is done and how scientific consensus is reached. Everyone serves on juries and must weigh evidence presented by scientists or by people representing themselves as scientists. Similarly, city councils, state and federal governments daily confront issues with scientific aspects. Doctors and lawyers and other profes-

sionals in many fields handle scientific issues in their work. Educating and informing our broader community must therefore be a prime goal of physicists and all scientists.

Within the US, the training of domestic students to fill a growing demand for scientists and engineers has fallen back substantially, and we have come to depend on importing large numbers of students and scientists. Now, new concerns for homeland security are preventing many scientists from entering the US and discouraging them from applying for jobs and training here. Secretary of Education Rod Paige has recently commented on this issue: “We have been relying on the education other countries provide to their citizens. There is something wrong when American schools cannot produce enough good workers for valuable American jobs.” He went on to suggest that “We need [improved science education] not just for our economy, but also for our national security.”

“Science and technology drive the economy,” according to Nobel Laureate Robert C. Richardson (July 6, 2004 *New York Times*). “The wealth of the country, I believe, is based on the invention of new products and that can only come from a thriving scientific community.” The state of education today then requires special efforts combining education and outreach with research. We need to support a pipeline that gains the interest of elementary school students with new and exciting science programs and keeps their interest with programs in middle, high school and beyond. This should include revitalized efforts to attract women and minorities into science.

The realm of education and outreach includes both formal and informal education. Formal education includes programs for students in kindergarten through twelfth grade. Informal education addresses lifelong learning and is even broader, including websites, after-school programs, science museums and a variety of educational materials. Many education and outreach programs cross the boundary between formal and informal and therefore reach wide audiences including both students and the general public. Many physicists report that their work with teachers and educators has increased their ability to communicate their science in informal settings.

In recent years spectacular new programs have had broad and deep successes. Many of these efforts have found ways to bring cutting-edge contemporary physics to the classroom, thereby inspiring a new generation of students and building new communities among teachers. New national programs are providing research experiences to students and teachers, professional development for teachers and curriculum enhancement.

These dynamic programs have gained broad recognition within the physics community bringing new respect to physicists who devote a portion of their time to education and outreach. Further efforts to reward young physicists for contributing to these programs would greatly enhance education and outreach efforts. Building on our many recent successes will bring outstanding domestic students to careers in science and develop a scientifically literate populace.

Connections

A strength of this education and outreach workshop was the reinforcement of existing bonds and the establishment of new links among research, formal education, informal education and information technology/media participants. Below we include representative examples of activities that we presented and discussed in the sessions. We have deliberately avoided providing a

comprehensive listing of the many excellent programs that currently exist or are in planning. That is beyond the scope of this effort.

1. Connections between Fundamental Science and Formal Education

Interactions between science and formal K-12 education include research experiences for teachers and students, professional development workshops, preservice education and instructional material development, with an emphasis on bringing real data to students. For example, teachers and high school students participate as collaboration members on scientific experiments through immersive research experiences at the Fermilab Tevatron and the CERN Large Hadron Collider (LHC). Activities include detector construction and assembly, computer simulation and data analysis, and dissemination of experiences to the classroom and broader audiences. The National Optical Astronomy Observatory develops teacher leaders by immersing them in research projects such as studying solar magnetic fields, the spectroscopy of giant and supergiant variable stars or flaring novae.

Student research experiences can be brought directly to the classroom. Students learn to collect and analyze their own data and to share and compare results with students from other schools. The Sloan Digital Sky Survey SkyServer offers access to public datasets with accompanying lesson plans. Through Hands-On Universe students can request their own images and take part in on-going projects like Jupiter Week. Programs such as CROP, WALTA and the QuarkNet Cosmic Ray Grid Project engage high school students in hands-on assembly, operation and networking of scintillation hodoscopes to study cosmic-ray air showers. Through inter-school, inter-class cooperation their collective data allows the study of cosmic-ray air showers.

Scientists can improve the training of future teachers by collaborating with colleges of education. For example, the UTeach program, a collaboration among the Colleges of Natural Sciences and Education at the University of Texas and the Austin Independent School District recruits, prepares and supports the next generation of math and science teachers for the State of Texas.

Many of the current E&O programs focus on students in grades 9-12. More grade-appropriate activities like Hands-on Solar System can help younger students develop knowledge and skills that lead to successful participation in the high school research activities. Programs like the Physics Van at the University of Illinois at Champaign-Urbana bring the excitement of science to students in earlier grades.

An important and non-trivial outcome of such activities is that research physicists learn about the issues and challenges that are faced by secondary teachers in teaching science in the classroom as well goals of meeting the education standards in their communities.

2. Connections between Fundamental Research and Informal Education

Development of museum exhibits that demonstrate or explain fundamental research is an important activity to bring forefront science to the general public and to school students. Whether building exhibits for a science center like the Laser Interferometer Gravity-Wave Observatory (LIGO) exhibit hall in Livingston, LA or for existing science museums, exhibits that characterize modern science and state-of-the-art research techniques require the scientific community to work alongside exhibit developers.

The Adler Planetarium and Astronomy Museum, through joint appointments of planetarium staff with the University of Chicago Department of Astronomy and Astrophysics, is an example of

such a bridge. Visuals such as the GeoWall developed by University of Chicago astrophysicists and their collaborators for the Sloan Digital Sky Survey are finding their way into planetarium exhibits at the Adler and elsewhere.

The Exploratorium has used the web to create "virtual field trips to real science," bringing the public access to the process of discovery. The museum becomes a mediator between the science location and the online audience at home and at school. These field trips may be associated with events such as the recent solar transit of Venus or with live connections to worldwide scientific locations and various space missions. For example, "Live @ the Exploratorium: Origins" visited six laboratories including CERN, the Hubble Telescope and Cold Spring Harbor Laboratory.

3. International Connections among Scientists and Educators

Scientists throughout the world are engaged in education and outreach and can inform advances in US programs. An exemplar is the House of Science at the University of Stockholm, which enriches the science education development of 10%-20% of the secondary school teachers and students in Sweden.

Connections between American scientists and educators and their counterparts in other parts of the world are imperative for improving physics outreach opportunities for American youth. An example is the USCMS Fellowship program that supports American high school teachers for travel to CERN to work on testing and preparations for the CMS Experiment at the LHC.

4. Connections between Scientists and the Media

David Kestenbaum, a science reporter for National Public Radio, and Lawrence Krauss, a noted astrophysicist and popular science writer, emphasized the challenges involved in presenting science in the media. Here we note the *disconnect* between the priorities of the media to rapidly engage, enlighten and entertain particularly with a negative story and the interests of the scientists to carefully and accurately present their work and its motivation.

6. Connections through Virtual Organizations

A very different, yet interesting, model of connections among scientists is the virtual Institute for Complex Adaptive matter, ICAM. The virtual character of the institute allows for effective interaction among participants without their relocation from their home institutes.

Significant New Steps

1. Workshop for Researchers

We propose holding a workshop for researchers new to education and outreach. They face numerous pitfalls and challenges, including understanding the needs of and how to communicate with teachers, understanding what educational research says about effective programs; finding an audience for and consumers of their materials; understanding the opportunities and limitations of the media for disseminating science and the role and audience of museums and science centers, and *not* reinventing the wheel. This workshop will bring together researchers with successful E&O programs and those interested in getting a head start on planning their own programs. Deliverables from this workshop will include a set of materials and a "consulting team" willing to assist their colleagues as they move forward with their activities.

2. Sessions for Department Chairs and New Faculty

We propose to offer sessions at existing meetings to address E&O issues. One issue we'd like to address is the lack of support and respect scientists receive for time spent on E&O. Physicists are urged to communicate the excitement and importance of physics to everyone, but it takes ongoing support from department chairs and deans to establish a climate that validates these efforts.

Another group we propose to reach is new faculty. New faculty present an attractive audience for this effort, since many are inexperienced in outreach and education, and reaching career scientists early helps establish an outreach-aware culture among the next generation of academics.

3. Publications, Archives, Listservs

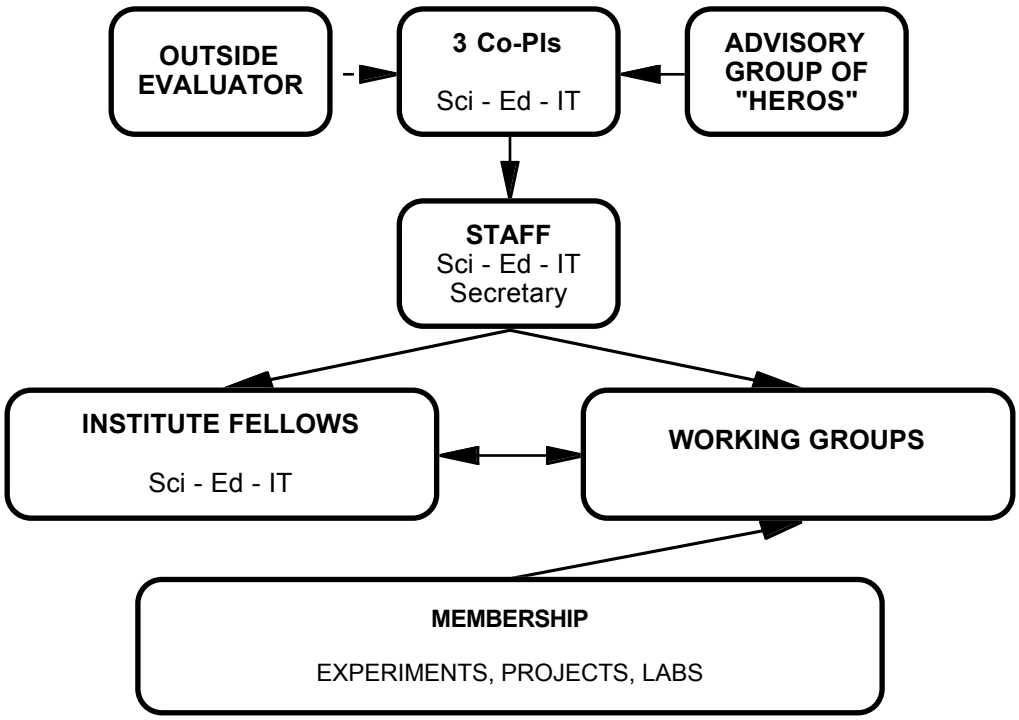
We discussed several ideas about sharing information about E&O programming and staying in touch. We might publish a booklet on E&O similar in quality to *The Quantum Universe.* We also talked about establishing a central place to publish E&O articles for the community. We will ask arXiv.org to establish a new archive epo-ph for papers on education & public outreach topics. Also, we will ask APS to set up an e-mail conversation list, say EPOPHYS, on EPO topics, akin to the existing one (WIPHYS) for women in physics.

4. Virtual Institute

While workshop participants have come from different physics disciplines, from different informal science initiatives and from different school districts, labs and education programs, we work in the same arena; our goals and needs are similar; our programs share similar components; our education partners are the same. Our work falls within the *Understand the Universe* framework that Marv Goldberg described in our phone meeting with NSF staff. At the same time, we recognize the effort to "federate" our science education and outreach initiatives needs will require other staff to provide structure, coordination and support. We propose a grassroots effort to promote and support new collaborative E&O efforts through a virtual organization.

For this report we provide a very preliminary mission statement and management structure. The mission of this "virtual institute" is to federate science education and outreach initiatives conducted by research experiments and centers, information technology initiatives, and informal education organizations, in order to better address critical national and local needs in education and general science literacy.

A possible management structure.



The leadership, a trio of Co-PIs, representing program areas of science, education and information technology/media, will rotate through three-year appointments. These will be volunteer positions with some organizational support for travel, etc.

An advisory group comprised of education and outreach “heroes” from the participating disciplines will advise the Co-PIs, and an outside evaluator will provide formative and summative evaluation.

The Co-PIs will direct a full-time staff drawn from the program areas, scientists to media, and a secretary. This staff, requiring a salary of approximately $300 K/year, will handle the operational details and operating expenses (including $200 K/year for travel, equipment, and miscellaneous needs). The staff will work in the same geographic area.

With the support from the staff and fellows, working groups composed of people from the program areas—science, education and information technology/media—will work on new collaborations of the member organizations. Institute fellows—postdocs, senior graduate students, teachers—will receive a stipend in return for directing a fraction of their time toward education and outreach. (See the NSF Astronomy & Astrophysics Postdoctoral Fellows Program as an example of a research/E&O postdoc fellowship). Salaries for 12 fellows, 4 per program area will cost ~$300 K (plus benefits) for 6 FTE.

5. Local K-12 Initiatives

Many teachers are frustrated because the resources that should support their efforts to teach the National Standards are not easy to obtain. Because the needs of individual teachers are

unique, it is essential to establish a direct dialogue between developers, providers, and users of teaching materials. Local, grass roots partnerships between universities, research institutions or museums and local school systems (GRP's) address community-specific needs and directly impact the teachers and students who are the "end users" of E&O resources.

Benefits derived from GRP's include:

- Addressing specific community needs such as minority and high-need students.
- Establishing lasting mentor/teacher relationships.
- Creating opportunities to raise the level of professional growth and reach teachers who would normally decline professional development.
- Directly disseminating materials to teachers.
- Establishing ongoing ties between classroom and student "field tips."
- Promoting the science pipeline for area students, particularly among non-traditional students.
- Providing recruiting avenues for universities.
- Recruiting and training preservice teachers.
- Easier logistics such as travel and local media support.

6. Adding Value to Existing Programs

Many existing education and outreach programs fall short of their potential impact because they are not well disseminated or because teachers run into implementation barriers. We propose that the virtual institute maintain an online "one-stop shopping" site for teachers to access materials and programs produced by the member organizations. The institute will establish some criteria for posted programs, for example: including explicit connections to national standards and curriculum requirements or incorporating effective ways to minimize teachers' efforts to understand and use materials, and assist program leaders in creating/adapting programs to meet those criteria.

Another mechanism for adding value to existing programs involves establishing a "dating service" to match scientists with existing education and outreach programs or with teachers, museums, etc. who are looking for partners. Automated matching tools could help the human overseers, especially if the programs and their potential utilizers provide sufficient detail on scope, level, standards addressed, etc.

Appendix A. Participant List

Physics Researchers

Family Name	First Name	Institution
Abrahams	Elihu	Rutgers University
Arnett	David	University of Arizona
Bando	Masako	Aichi University, Japan
Barnett	Michael	Lawrence Berkeley National Laboratory
Berns	Hans	University of Washington
Campbell	David	Boston University
Chivukula	R. Sekhar	Michigan State University
Claes	Dan	University of Nebraska, Lincoln
D'Hoker	Eric	University of California, Los Angeles
Dorsey	Alan	University of Florida
Durand	Bernice	University of Wisconsin
Durand	Loyal	University of Wisconsin
Hooper	Eric	University of Texas at Austin
Hubler	Alfred	University of Illinois, Urbana-Champaign
Johansson	Erik	Stockholm University, Sweden
Krauss	Lawrence	Case Western Reserve University
Murayama	Hitoshi	University of California, Berkeley
Pascolini	Alessandro	Padua University, Italy
Pines	David	University of Illinois, Urbana-Champaign
Pompea	Stephen	National Optical Astronomy Observatory
Ruchti	Randy	University of Notre Dame
Simmons	Elizabeth	Michigan State University
Snow	Greg	University of Nebraska, Lincoln
Surendran	Dinoj	University of Chicago
Tuner	Michael	NSF/University of Chicago
van der Veen	Jatila	University of California, Santa Barbara
White	Andy	University of Texas, Arlington
Wilkes	Jeff	University of Washington

Family Name	First Name	Institution
K-12 Teachers		
French	Laura	Roaring Fork High School
Keyes	Irene	Naussau Elementary School
Kruis	Diana	Basalt High School
Rittner	James	Baltimore Polytechnical Institute (HS)
Rogers	John	Westside High School
White	Doretta	Meacham Middle School
Whitley	Marc	Aspen High School
Other Educators		
Bardeen	Marge	Fermi National Accelerator Laboratory
Clark	Jessica	American Physical Society
Coshow	Suzanne	University of Notre Dame
Davis	Jason	Cleveland Museum of Natural History
Johnson	Michelle	SciTech Hands-on Learning Museum
Kestenbaum	David	National Public Radio
Landsberg	Randy	University of Chicago
Marchant	Beth	University of Notre Dame
Meredith	Kate	Classroom teacher currently domestic god-dess
Semper	Rob	Exploratorium
SubbaRao	Mark	University of Chicago & Adler Planetarium

Appendix B. Workshop Program

Week I: June 28 - July 2

Speaker	Title	Activity	Time
Rob Semper	Virtual Field Trips to Real Science	Talk	Tue 10AM
Randy Landsberg	From the Frontiers of Physics to the Museum Floor	Talk	Tue 3PM
Mark SubbaRao Dinoj Surendran	Visualizing the SLOAN Digital Sky Survey and Other Data Sets in 3-D Stereo	Demonstration	Wed 10AM
Michael Barnett	Outreach in the ATLAS Experiment	Talk & Video	Wed 3PM
Rob Semper Erik Johanssen Mark SubbaRao Allesandro Pascolini	Panel Discussion on Informal Education	Panel	Thu 10AM
Rob Semper	The Exploratorium at 35	Colloquium	Thu 3PM
Allesandro Pascolini	The Effectiveness of Exhibitions in Science Communication and how to Produce a Good One.	Talk	Fri 10AM
Masako Bando	Comments from Japan: Possible Experiments for Big Classes What Images Japanese Students Have About Einstein The Role of Women Scientists in Science Societies	Talk	Fri 1PM
David Pines Elihu Abrahams	Outreach in Condensed Matter Physics	Talk	Fri 3PM

Week II: July 5 - July 9

David Kestenbaum	My Father Sees Muons in the Driveway or How to Explain Physics to Everyone Else	Talk	Mon 4pm
Marge Bardeen	QuarkNet Overview	Project Overviews	Tue 10am
Steve Pompea	NOAO Experiments in Science Education: Lessons Learned	Project Overview	
Jatila van der Veen	Labs for a Lambda Dominated Universe		Tue1:30pm
Liz Simmons Bernice Durand	How to Prepare a Public Lecture	Talk & Audience Participation	Tue 3:15pm
Kate Meredith	Hands on Universe	Discussion	Wed 9am
Erik Johansson	House of Science - A New Complementary Approach to Experimentation in Natural Science	Talk	Wed 10am
Eric Hooper	Discussion of Career Choices: The Balance of Research and Education & Outreach	Group Discussion	Wed11:15am
Randy Landsberg Dinoj Surendran Mark SubbaRao Rob Semper Jason Davis Greg Snow Andy White Michael Barnett Randy Ruchti	Session on Education and Outreach Visuals (or The Aspen Center for Physics Video Festival)	Video Presentations	Wed 1:00pm
Marge Bardeen Beth Marchant	QuarkNet Cosmic Ray Project	Demonstration	Wed 3pm
Lawrence Krauss	Science Writing	Group Discussion	Wed 4:30pm
K-12 Teachers	K-8 Formal and Informal Education Issues	Discussion	Thu 9am
Greg Snow	CROP - Lessons Learned	Talk	Thu 10am
John Rogers	CROP - Teacher Perspective	Talk	
Dan Claes	CROP - Colorado Schools at the Henderson Mine	Talk	
Jeff Wilks	WALTA	Talk	
Women ACP Attendees	Lunch	Discussions	Thu 12:30
E&O Working Group & NSF MPS & EHR	Technical Merit and Broader Impacts Issues	Teleconference	Thu 1pm

Appendix C. Dissemination Activities Stemming from the Workshop

The organizers and participants plan to disseminate the results of the workshop as broadly as possible, through written articles, conference presentations and meetings with representatives of funding agencies.

Written Media:

- Workshop Report: will be distributed to funding agencies, members of HEPAP and the education & outreach coordinators of ICAM, APS and the national labs.
- Invited Physics Today article on "Physics Outreach."
- Contributed APS News "Back Page" article.

Electronic Media:

- The workshop website www-ed.fnal.gov/aspen/ will include this report, slides from the conference presentations, and annotated links to resources of use to education & outreach practitioners.

Conference Presentations:

- Contributed talk (Campbell, Semper), Frontiers in Correlated Matter Symposium, Snowmass, CO, 5-8 August 2004. Sponsored by the Institute for Complex Adaptive Matter. frontiers.physics.rutgers.edu
- Plenary talk (Simmons), Meeting of the Division of Particles and Fields of the American Physical Society, Riverside, CA, 26-31 August 2004. dpf2004.ucr.edu
- Contributed talk (Barnett, Marchant), 129th National Meeting of the American Association of Physics Teachers, Sacramento, CA, 31 July – 4 August 2004. www.aapt.org
- Contributed talk (Johansson, Snow), Meeting of the European Particle Physics Outreach Group, CERN, Geneva, Switzerland, October 2004. outreach.web.cern.ch/outreach/
- Contributed talk (Bardeen, Marchant), 130th National Meeting of the American Association of Physics Teachers, Albuquerque, NM, 8-12 January 2005. www.aapt.org
- Contributed talk (Hooper), 205th Meeting of the American Astronomical Society, San Diego, CA, 9-13 January 2005. www.aas.org/publications/baas/v36n5/aas205/1613.htm also noted in the NASA ADS Astronomy/Planetary Abstract Service.
  Astronomy Camp Poster www-ed.fnal.gov/aspen/talks/aspen_camp.ppt
  UTeach Poster www-ed.fnal.gov/aspen/talks/uteach.ppt

Future presentations

- We have discussed with the Education/Outreach Officer of the APS the importance of having regular sessions on education outreach at the annual APS/AAPT Workshop for New Physics Faculty. This is especially important for new faculty who are seeking for ways to ensure that they are fully apprised of broader impacts issues and opportunities, all-important now for federal funding of research.
- We will strive to impress upon the officers of the APS and AAS the importance of having plenary and parallel sessions devoted to education and outreach topics at all scientific meetings.
- We are requesting time at the Sept. 2004 HEPAP meeting to present this workshop report, focusing on the aspects most relevant to particle physics.

Appendix D: History of Effort Culminating in Workshop

The Aspen Education and Outreach Workshop is another in a series of grass roots meetings to explore ways for people from three frontiers, physics science research, computer science research and technology and research on the science of teaching and learning to collaborate on E&O initiatives. The first meeting was a Needs Assessment and Developers Meeting for Grid Techniques in Introductory Physics Classroom Projects held at Florida International University in conjunction with the American Association of Physics Teachers Annual Meeting in January, 2004. The second meeting was a Discussion Meeting on Education and Outreach: "Developing a National Initiative" held at Arlington VA in April 2004. Reports from these meetings are online at <www-ed.fnal.gov/uueo/meetings.html>.

Appendix E: Workshop Evaluation Summary

Methodology: At the conclusion of the workshop, participants completed a brief evaluation of the workshop listing the most important positive parts of the workshop and places where there was room for improvement. All present completed the survey; those who had attended earlier parts of the workshop were requested to complete the evaluation via e-mail.

Summary of Positive Comments

Learning
The most abundant comments indicated the participants' appreciation for what they had learned by attending the workshop: information about other projects, other disciplines, and importantly, the perspectives of others concerned with education and outreach who are different than themselves (e.g., teachers for researchers).

Participant Diversity
The majority of the participants commented on the value of the diverse mix of participants in the workshop. People stressed the importance of being informed by other disciplines, other types of education and outreach practitioners, global perspectives, journalists, authors and NSF staff.

Cross-Disciplinary
Related to the broad range of attendees, many participants cited the value of bridging disciplines. A number of new cross-disciplinary ideas were identified as being seeded by the interactions at the workshop.

Networking
The impact of networking with peers and non-peers was considered by many to be a key part of the workshop.

Structure
The informality and ability to hold numerous and informal discussions were both seen as vital to success.

Location
The location, including the population of the Aspen Center for Physics, was viewed as a positive factor for the workshop.

Summary of Suggestions for Improvement

Structure
Improved organization and pre-workshop planning were recommended, to encourage broader participation from the physics and formal education communities, involvement of additional agencies e.g., NASA and DOE, and more K-8 focus. More time was suggested for discussions, with less emphasis structured time, to allow for the development of new ideas. Practical matters were mentioned such as the benefit to all participants by routine use of name tags.